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# Correlation between spinopelvic angles and radiological findings of lumbar spondylolisthesis patients

Engin Yücel[1], Yener Akyuva[2]

[1]Department of Neurosurgery, Alanya Alaaddin Keykubat University Training and Research Hospital, Antalya, Turkey
[2]Department of Neurosurgery, Tayfur Ata Sökmen Medical Faculty, Hatay Mustafa Kemal University, Hatay, Turkey

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## ABSTRACT

**Aims**: Spondylolisthesis is a deformity in which the upper segment is displaced anteriorly or posteriorly in the spine relative to the lower segment. In this pathology, which often causes instability, surgical treatment may be required. Also, patient's radiological images should be evaluated carefully before treatment. We aimed to analyze clinical and radiological data with spinopelvic angles of the lumbar spondylolisthesis patients in our research.

**Methods**: 6593 patients who applied to the neurosurgery outpatient clinic with complaints of low back pain between January 2019 - December 2022 were retrospectively analyzed. The radiological findings of patients with spondylolisthesis, whose lumbar MRI and lumbar CT were obtained appropriately along with X-ray were evaluated in detail. Age, gender, listhesis level and degree, Cobb angle, pelvic incidence, pelvic tilt, sacral slope angle, Modic degeneration, vacuum phenomenon, annulus rupture, Schmorl nodule, facet hypertrophy, osteophyte, maximum AP central canal diameter and joint lysis has been examined in these patient tests. The relationships of these data with each other were evaluated statistically.

**Results**: 58 female and 5 male patients were found to be eligible for the study. Mean age was 59 (min 22, max 81). Grade 1 listhesis was detected in 52 of the patients. Listhesis was observed at the level of L5-S1 in 31 patients, L4-L5 in 24 patients and L3-L4 in 8 patients. A direct correlation was found between age and vacuum phenomenon, osteophyte, presence of L5-S1 listesis and lysis. Similar correlation was found between pelvic incidence and sacral slop angle, facet hypertrophy and Modic type 2 degeneration. Also, there was a direct correlation between pelvic incidence and pelvic tilt; between facet hypertrophy and vacuum phenomenon and lysis; ligamentum hypertrophy and vacuum phenomenon; and facet hypertrophy and lower level listesis (p 0.05).

**Conclusion**: Spondylolisthesis is an important problem that requires treatment in spine surgery. Radiologically determined parameters can give important knowledge about the severity of this pathology. These findings should be taken into consideration in the treatment of spondylolisthesis.

**Keywords**: Spondylolisthesis, radiological parameter, spinal deformity, instability, spinopelvic angles

## INTRODUCTION

Spondylolisthesis develops after the vertebrae move forward or backward on each other.[1] It usually occurs at the L4-5 level and rarely in adjacent segments. Degenerative spondylolisthesis is common in women after the age of 50.[2] The reason for its frequent occurrence in women is known to be the more ligament laxity than men. In women, especially during pregnancy, maternal hormones increase joint laxity and initiate a pathological process for spondylolisthesis.[3] It appears as a wide clinical spectrum ranging from simple mechanical low back pain to progressive neurological deficits and radiological findings. It is a serious public health problem as it causes workforce loss.[4]

In degenerative lumbar spondylolisthesis, pathologies begin with intervertebral disc and facet joint degeneration. After the development of degenerative disc disease, most of the loads on the lumbar region are transferred to the facet joints. After this microinstability caused by progressive degeneration, hypertrophy and osteophyte formation begins in the facet joint. After this change, the tension and ligament loosening occurring in the facet capsule may lead to forward or lateral shifts in the vertebrale column. Other radiological findings such as disc space height loss, facet hypertorophy, ligamentum flavum hypertrophy, subchondral sclerosis, osteophyte formation, spinal stenosis and foraminal stenosis may accompany the spondylolisthesis.[5-7] Age, gender, occupation, trauma are the main known causes of spondylolisthesis, and although

**Corresponding Author**: Engin Yücel, drengin2005@yahoo.com

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there are many studies on this topic, a clear relationship has not yet been absolutely established between clinical and radiological findings and spinopelvic angles in terms of the development of spondylolisthesis.[8-12] In our study, radiological findings, spinopelvic angles and clinical findings in patients with spondylolisthesis were evaluated and compared in detail.

## METHODS

The study was carried out with the permission of the Hatay Mustafa Kemal University Non-interventional Researches Ethics Committee (Date: 01.09.2022, Decision No: 32). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

6593 patients who applied to the neurosurgery outpatient clinic with complaints of back and leg pain between January 2019 and December 2022 were retrospectively analyzed. Among the patients with spondylolisthesis, X-ray (lateral, anteroposterior), lumbar magnetic resonance imaging (MRI- 1.5 T T2, T1 sequence sagittal, T2 sequence axial section) and lumbar computed tomography (CT- sagittal-axial-coronal section) were obtained from 63 patients having appropriate radiological tests and evaluated in detail. Patients with a previous history of spinal surgery, spinal tumor, congenital malformation or major trauma exposure were not included in the study. The common feature of the patients was lumbar degenerative spondylolisthesis. In these patients, age, gender, listhesis level, listhesis degree, Modic degeneration, presence of osteophyte, facet hypertrophy, maximum antero-posterior central canal (MAPCC) length, pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS) angles, vacuum phenomenon, Cobb angle, joint lysis, anulus rupture, Schmorl nodule and the relationships between these data were evaluated statistically.

PI, PT, SS and Cobb angles were calculated using the Clear Canvas program from one researcher who is dealing with spine surgery. While performing lumbar CT of the patients, it had been checked that CT was taken from the upper end plate of the L1 vertebra to the femoral head of pelvis. The PI was determined by calculating the angle between the vertical line drawn down from the midline of the sacral plateau in the sagittal plane and the line drawn from the same point to the femoral head (**Figure 1A**).[13] The SS was calculated as the angle between the sacral plateau and the horizontal plane (**Figure 1B**). PT was found by calculating the angle between the line drawn from the midpoint of the sacral plateau to the femoral head and the vertical plane (**Figure 1C**).[14] Scoliosis angle was determined with the plane drawn from the upper and lower ends of scoliosis in patients with lumbar scoliosis (**Figure 1D**).[15] Listhesis level (**Figure 2A, 2B**) and degree (**Figure 2A, 2B**), Modic degeneration type (**Figure 3**), vacuum phenomenon (**Figure 4A**), MAPCC diameter at the listhesis level (**Figure 4B**), ligamentum flavum thickness (**Figure 4C**), facet degeneration (**Figure 4D**), osteophyte (**Figure 4E**) and Schmorl nodule (**Figure 4F**) were evaluated from lumbar MRI and CT images of the patients.

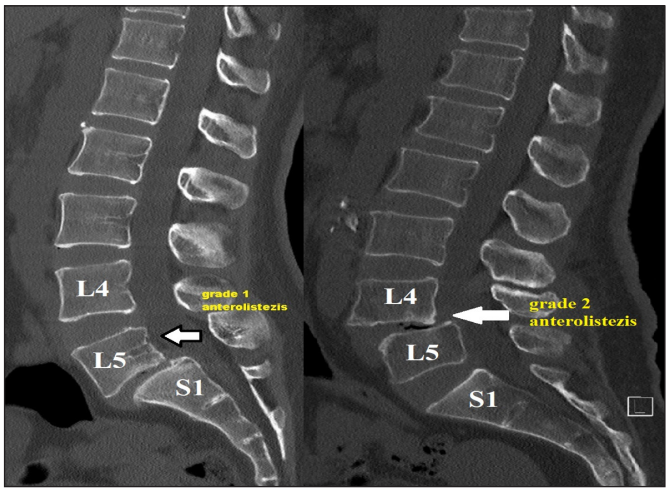


**Figure 2**

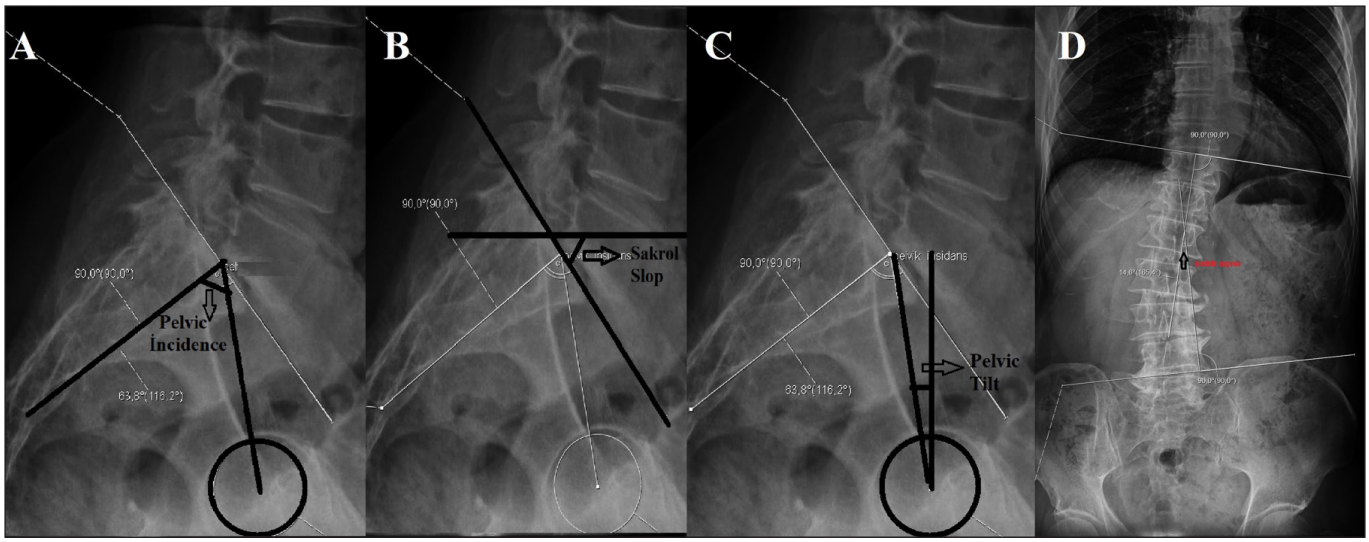


**Figure 1**

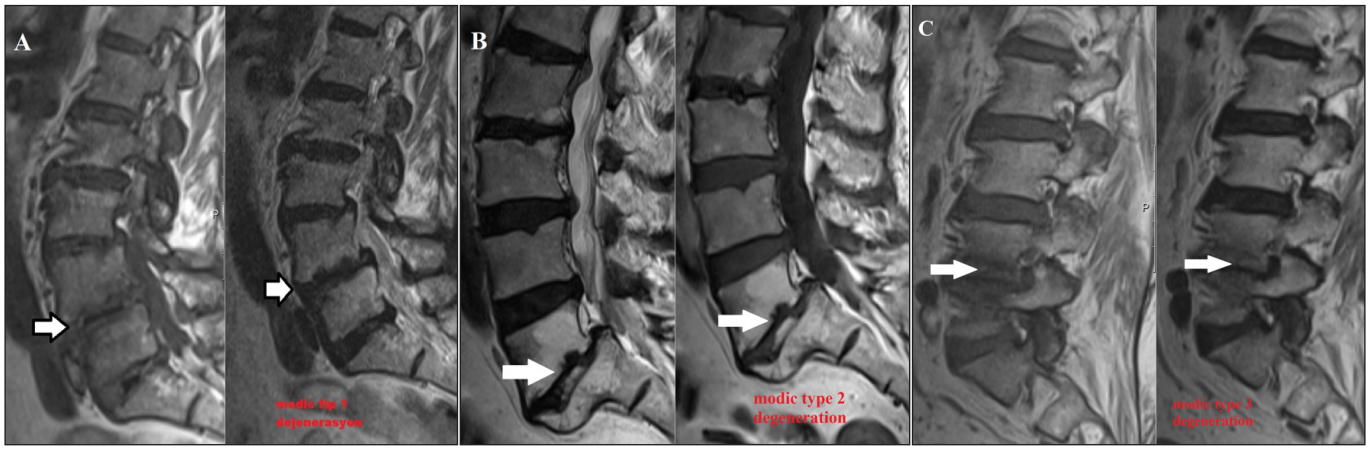


**Figure 3**

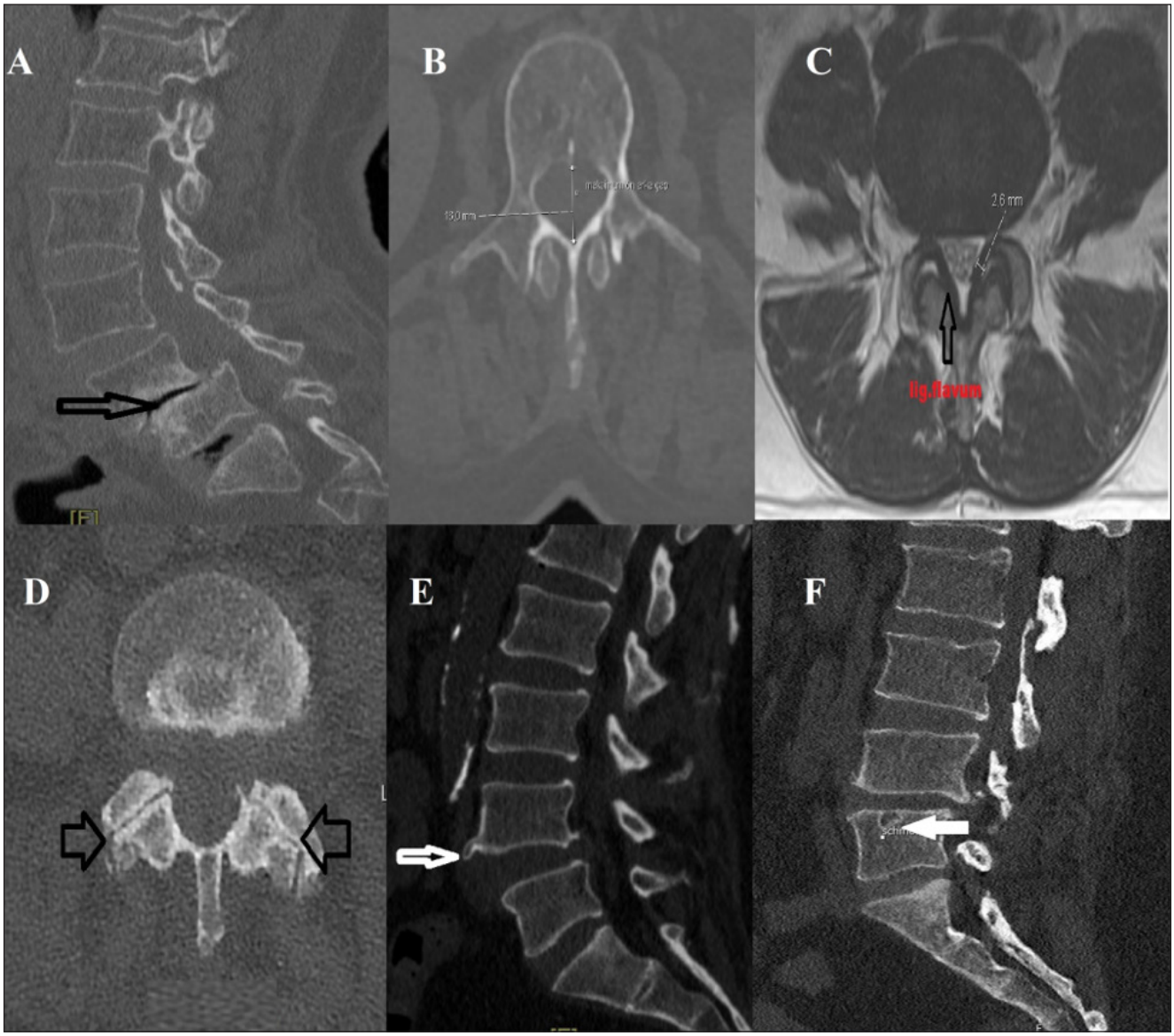


**Figure 4**

### Statistical Analysis

SPSS v21.0 for Windows (IBM Corp., Armonk, NY, USA) was used to analyze data. Means±standard deviations were used for normally distributed continuous variables [p>0.05 in Kolmogorov-Smirnov test or Shapiro-Wilk]. Correlation between facet hypertrophy, Modic degeneration, anulus rupture, vacuum phenomenon, MAPCC, spondylolisthesis levels, lysis defect and spinopelvic angle in the groups was measured by the Pearson correlation test (r). A p value below 0.05 was regarded as statistically significant.

## RESULTS

The population of our study consists of 58 females and 5 males, totally 63 patients. Grade 1 spondylolisthesis was detected in 52 patients, and grade II spondylolisthesis in 11 patients. Spondylolisthesis was present at L5-S1 level in 31 patients, L4-L5 in 24 patients, and L3-L4 in 8 patients. The mean age was found to be 56.89±12.21 years. The mean SS angle was 36.89±7.66, the PT angle was 22.73±3.64, and the PI angle was 68.37±7.79. Local lumbar Cobb angle was found to be 34.22±5.28 degrees in patients with degenerative scoliosis (n: 8). When the axial sections were examined, it was seen that MAPCC (CT) was 15.59±5.67 mm and the thickness of the ligamentum flavum (MRI) was 4.71±1.29 mm. Facet hypertrophy was detected in 42 patients. Nine patients had type 1, 24 patients had type 2, and three patients had type 3 Modic degeneration. Modic degeneration was not detected in 27 patients. Vacuum phenomenon was seen in 32, anterior osteophyte in 48, anulus rupture in 11, and Schmorl nodule in 16 patients (Table).

**Table.** Demographic and radiological information of patients

| | |
|---|---|
| Gender | |
| Male | 5 |
| Female | 58 |
| Grade | |
| I | 52 |
| II | 11 |
| Level | |
| L3-4 | 8 |
| L4-5 | 24 |
| L5-S1 | 31 |
| Average age | 56.89 ±12.21 |
| Pelvic parameters | |
| Sacral Slope | 36.89 ±7.66 |
| Pelvic Tilt | 22.73±3.64 |
| Pelvic Incidence | 68.37 ±7.79 |
| Local cobb angle | 34.22 ±5.28 |
| Maximum antero-posterior central canal | 15.59 ±5.67 |
| Ligamentum flavum thickness | 4.71 ±1.29 |
| Facet hypertrophy | |
| + | 42 |
| - | 21 |
| Modic degeneration | |
| - | 27 |
| I | 9 |
| II | 24 |
| III | 3 |
| Vacuum phenomenon | 32 |
| Anterior osteophyte | 48 |
| Annulus rupture | 11 |
| Schmorl nodule | 16 |

There was a negative correlation between SS and facet hypertrophy, and a weak positive correlation with Modic degeneration (r=-0.383, p=0.003 and r=0.310, p=0.01, respectively). There was a negative correlation between PI and anulus rupture (r=-0.327, p=0.013). There was a weak negative correlation between facet hypertrophy and Modic degeneration, vacuum phenomena (r=-0.347, p=0.008 and r=-0.275, p=0.039, respectively). There was a weak negative correlation between MAPCC and flavum thickness (r=-0.311, p=0.018). There was a weak positive correlation between vacuum phenomenon and disc level, lysis defect (r=0.309, p=0.019 and r=0.312, p=0.018, respectively). There was a weak negative correlation between lysis defect and facet hypertrophy, and weak positive correlation between Modic degeneration and vacuum phenomenon (r=-0.365, p=0.005, r=0.325, p=0.014 and r=0.312, p=0.018, respectively). There was a moderate positive correlation between lysis defect and disc level (r=0.555 p=0.0001).

## DISCUSSION

Studies on spondylolisthesis found that the PI was greater before dislocation and degeneration began, so lumbar lordosis and also the SS angle were higher in patients than in the normal population. With the increase of lumbar lordosis, an excessive load is placed on the posterior facet joints. This mechanical stress on the facet joints results in facet arthrosis. After facet arthrosis, the SS angle is affected and causes a situation predisposing to listhesis. Spondylolisthesis is followed by intervertebral disc degeneration and collapse. Sagittal vertical axis shifts forward. As a result of compensatory mechanism in degenerative spondylolisthesis cases; pelvic retroversion is expected with a decrease in the SS angle and an increase in the PT angle.[16-18] Therefore, it is important to plan the treatment by considering the accompanying radiological findings of the evaluation for the spine and pelvis in patients with spondylolisthesis.

Pelvic morphology and spinopelvic balance abnormalities are among the most important factors causing the development of spondylolisthesis. Legaye et al.[19] reported the PI as 50.2±10.6 in the normal elderly population, while this angle was 62±11 in patients with listhesis. Also, Liu[20] and Funao[21] likewise showed that PI was higher than the normal population in their study. In our study, the PI was found to be 68.37±7.79, consistent with the literature. Likewise, the data in our study support that the PT angle is higher (22.73±3.64) and the SS angle is lower (36.89±7.66) than the range of the normal elderly population in the literature.

The data of our study showed that the spinopelvic parameters are different from the normal population in accordance with other studies in the literature. These results, although not proven, support that they develop due to a compensatory mechanism in spondylolisthesis. Kırceli at al.[22] emphasized in their study that LL and SS

angles may be a predisposing factor for the development of disc degeneration. Ergun at al.[23] found that the degree and risk of intervertebral disc degeneration and herniation increases in parallel to the decrease in sacral kyphosis and LL, and to the increase in SS angle. Considering that spondylolisthesis is a pathology that develops on the basis of intervertebral disc degeneration, the data in our study support that the spinopelvic angles change depending on the compensatory mechanism.

Lazenec et al.[17] mentioned about the relationship between radiological parameters and postoperative pain in lumbosacral fusion. Spinopelvic angles are disrupted in patients with spondylolisthesis. These patients usually complain of ongoing postoperative pain. In our study, distorted spinopelvic angles were found as compared to the normal population. At the same time, it was thought that the positive correlation in our study between spondylolisthesis and radiological findings such as Modic degeneration, joint lysis, vacuum phenomenon indicates more bone damage. These datas suggested that before the surgery surgical team should evaluate the patient better, and the patient's satisfaction from the treatment could be increased by performing peroperative corrective interventions, if necessary.

In our study, there was a negative correlation between spondylolisthesis and facet hypertrophy, anulus rupture; and a positive correlation between Modic degeneration and osteophytes. These findings showed us that the possibility of listhesis development is reduced after facet hypertrophy, secondary to this stronger bone formation. On the contrary, it is concluded that if facet hypertrophy does not develop, lysis occurs after with microtraumas, the Modic degeneration process starts after traumas in the vertebra, and osteophyte development is seen secondary to the efforts to reconstruct the bony column. Grobler et al.[18] argued that lumbar facet morphology is one of the most important etiological factors in the development of spondylolisthesis and facet degeneration has a major determinant role in this issue, in accordance with the data in our study.

There was no clear relationship between the symptoms caused by spondylolisthesis and central canal stenosis. However, in our study, a negative correlation was found between facet hypertrophy and listhesis, and the central canal anteroposterior distance was found in the normal population range. Although it is named as lumbar degenerative spondylolisthesis, when compared to the studies on spinal stenosis in the literature; both ligamentum flavum thickness and MAPCC values are close to the normal population in spondylolisthesis patients. Considering that Modic type 1 and type 2 degenerations are more frequently detected in our patients, it is thought that the pathological degenerative processes due to inflammatory and fatty degeneration resulting from microtrauma are the main determinants.

Especially joint laxity and pregnancy are the most important factors in the development of spondylolisthesis in the female population.[4] Therefore, it is expected to be more common in women. In our study, 58 patients (92%) consisted of women, in parallel to the literature. Our study was conducted on patients who were admitted to a local hospital that appeals to the socioculturally lower class. The common feature of female patients in this population was the high body mass index (BMI) and the presence of multiple birth history. In cases of obesity and multiple pregnancy, the load carried by the pelvis increases towards the anterior due to the displacement of the center of gravity. Since our study is a retrospective study, the BMI and number of births of these patients could not be included in our study. However, while L4-L5 listhesis was observed more frequently in the normal population, it was thought that the higher prevalence of L5-S1 listhesis (n: 31) in our study may be related to this issue.

Some studies in the literature emphasize that more frequently seen spondylolisthesis in women cannot be explained by paraspinal muscle mass and ligament laxity. Also, pelvic type and morphometry may be an important factor in the development of spondylolisthesis. Boulay at al.[24] stated in their study on 12 anatomic pelvis specimens that, pelvis morphology can be used to examine the relationship between pelvis anatomy and spinal curves. In addition, they believe that the pelvis type could be one of the predisposing factors in degenerative spinal pathologies.

In our study, scoliosis was found in 8 patients. Cobb angles were determined between Min:25.7°- Max:45.6° (34.22±5.28). In our study, scoliosis with a minor degree were ignored, and scoliosis greater than 20° were included. These values indicate that spondylolisthesis may be not only be a sagittal but also an axial balance pathology. Seitsalo at al.[25] stated that scoliosis accelerates degeneration and is a disease associated with spondylolisthesis. He reported that the rate of scoliosis with listhesis was higher when minor angle scoliosis was taken into account.

## Limitation

Our study is retrospective in nature, and therefore, not all requested information could be obtained from the patients. Information regarding the BMI values and the number of pregnancies of the patients was not recorded in the system; hence, it could not be included in the research data. Data pertaining to patients' pain, functional status, and neurological deficits, as well as instability findings in dynamic radiographs, were not mentioned in the study because they were not archived in the patient files.

## CONCLUSION

Spondylolisthesis often requires treatment. Radiologically determined parameters can give important clues regarding the severity of this pathology. When evaluating a patient with spondylolisthesis, it is important to measure the spinopelvic parameters. Detailed radiological evaluation is required treatment planning of spondylolisthesis.

## ETHICAL DECLARATIONS

**Ethics Committee Approval:** The study was carried out with the permission of the Hatay Mustafa Kemal University Non-interventional Researches Ethics Committee (Date: 01.09.2022, Decision No: 32).

**Informed Consent:** Because the study was designed retrospectively, no written informed consent form was obtained from patients.

**Referee Evaluation Process:** Externally peer-reviewed.

**Conflict of Interest Statement:** The authors have no conflicts of interest to declare.

**Financial Disclosure:** The authors declared that this study has received no financial support.

**Author Contributions:** All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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